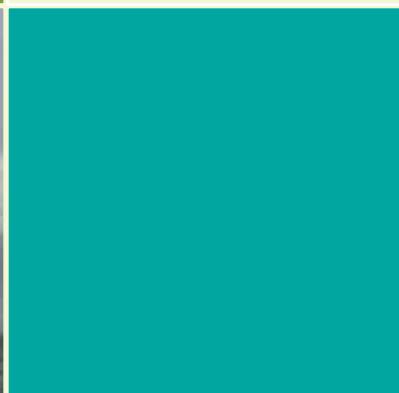


THE GAME OF LIFE AND DEATH



Students discover how natural selection helps animals adapt to their environment.



By Lindsay Todd, Lisa Keim, and Dale Broder

Evolutionary approaches are helping us solve important problems like antibiotic resistance in medicine, crop breeding in agriculture, and mitigation of the effects of climate change in the environmental sciences. Excitingly, we now know that students are capable of understanding evolution in elementary school and that early exposure reduces misconceptions and leads to more positive attitudes toward evolution (Nadelson et al. 2009). Unfortunately, many elementary school teachers are not prepared to teach evolution (Glaze and Goldston 2015) in part because evolution by natural selection has not been part of elementary school curriculum until recently (NGSS Lead States 2013). Therefore, we are in need of engaging teaching resources that are based on the *Next Generation Science Standards* (NGSS). Inquiry activities are effective (Minner, Levy, and Century 2010; Nadelson et al. 2009) and elementary-level learning is facilitated by programs that are “story-like, hands-on, active, student-creative, and fun” (Fail 2008). We created a self-guided, story-like game with creative drawing for grades 3–5 that teaches the evolution concepts of adaptation, natural selection, ecosystem dynamics, inheritance, and mutation following the NGSS (See Connecting to the NGSS on p. 59). Drawing reinforces concepts through emphasis on students’ hands-on interaction with the material (Ainsworth, Prain, and Tytler 2011)

and games result in greater retention of concepts because students are more engaged (Oblinger 2004). Elementary school students are especially receptive to games as a non-traditional teaching method because their generation has grown up with a saturation of technology and gaming (Oblinger 2004).

Our overall goal for this game was to expose students to the key elements of evolution by natural selection: variation, inheritance, selection, and time (See Figure 1 for learning objectives). We specifically targeted our program to grades 3–5 because it is at this point that evolution by natural selection is included as a standard for the first time (NGSS Lead States 2013). This allowed for us to provide a needed learning tool at the earliest educational point possible for the topic. Furthermore, we developed the program with fourth-grade students as they are in the middle of the recommended range, grades 3–5. We had an existing partnership with a school in Greeley, Colorado, where fourth graders had no science background and were from a community that is 90% English as a second language. By developing the program through our partnership, we were provided the means to ensure that the language and execution of the game could be understood by a range of students regardless of educational background.

Round 1: Getting Started

Students formed groups of four players and each group received a bag of materials: four coins, a die, colored pencils, and four activity booklets (see NSTA Connection). We first introduced variation. As a group, students determined the type of aquatic animal that they wanted to be—each student played the game as a different individual in a population of animals. In our class, two groups decided to be sharks, while other groups chose starfish, turtles, jellyfish, seahorses, and fish. The next steps are shown in Figure 2, p. 56, an example from one student’s activity booklet. Each student flipped his/her coin to determine his/her animal’s characteristics in five basic categories: coloration (bright vs. dull), size (large vs. small), defenses (armored spines vs. no armor), speed (fast vs. slow), and grouping (always alone vs. always with others; Figure 2A). Students drew their interpretation of their animal in the coral reef habitat provided (Figure 2B). Because every student drew an animal with unique traits, there is variation in the population (Figure 3.1, p. 57).

Now the fun begins with natural selection! Some of the animals are not able to survive and reproduce in each of the three rounds of the game. In the first scenario, sharks eat half of the population. Students predicted how their animal would perform in this environment. One student wrote “I think it going to do good cause [sic] we can protect each other,” referring to the fact that their animal was social and lived in a group. Another student said, “I will not be good for the environment [sic] because I am slow and I have no spines and I am by myself.” Next each student scored his/her animal based on its

FIGURE 1

Learning objectives.

1. Understand that certain traits make organisms more or less likely to survive and reproduce in a given environment
2. Understand that traits that are well suited to a given environment are more likely to get passed on from parents to offspring in the next generation, or inherited
3. Understand that when an environment changes, animals may no longer be well suited—they may survive or die
4. Understand that humans can cause changes in environments that act just like natural selection even though they are manmade
5. Recognize that not all mutations will result in recognizable trait changes
6. Understand how beneficial, harmful, and neutral mutations can arise and potentially result in a change in phenotype

five starting characteristics. They earned points for traits that offered an advantage in this environment (e.g., fast speed) and earned no points for harmful or neutral traits (e.g., bright color; Figure 2C). Only the animals with the highest scores survived and reproduced; thus the natural selection was based on an animal's traits and was nonrandom (Figure 3.2). In each scenario, each student answered questions about his/her animal's survival and reproduction due to the selective pressures as well as in comparison to other animals in the population (Figure 2D).

Round 2: Inheritance

Next, we introduced inheritance. The two surviving animals passed on their traits to the next generation, and each student flipped a coin to determine which copy of the trait he or she inherited, one from mom or one from dad. Each player adopted these new characteristics for the next round, discarding previous versions of their animals (Figure 3.3). We also included mutation events during reproduction (Figure 3.3). Each student rolled the die to determine the random mutation his/her animal gained during each reproduction event (at the end of each round). Some mutations resulted in beneficial traits (e.g., a dance that attracts attention from mates), while others hindered the animal's chance of surviving and reproducing (e.g., easily gets sick). Importantly, some players rolled mutations that resulted in neutral trait changes while still others rolled a mutation that did not result in any change in phenotype. Several students got the mutation "feathers" and were confused—they asked what purpose feathers would serve for an aquatic animal. We explained that not all traits serve a purpose. This illustrates the idea that mutations do not always result in "superhero-like" characteristics and instead can cause beneficial, harmful, neutral, or even unseen trait changes.

Round 3: All About Environment

Finally, the element of time is central to the game since each of the three rounds represents a new generation (Figure 3.4). The first round was a coral reef environment with many predators (natural selection). Round 2 focused on sexual selection via mate choice. Those traits that helped animals survive and reproduce in the high-predation environment in round 1 may

FIGURE 2

Game steps.

Sample Pages from Activity Booklet

To Begin:

- Get in groups of at least 4 players.
- In this game you are all the same type of animal that makes up a group. You live on a coral reef. As a group, choose what type of animal you all want to be. (For example you can be slugs, fish, sea stars, crabs, squid, etc.)

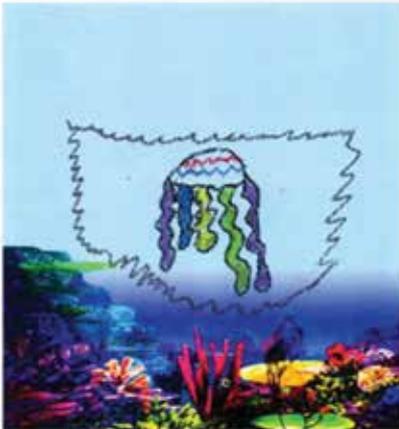
Write your animal type here: Jellyfish

- Now each of you flips your own coin 5 times. Each flip determines which type of one of the 5 traits listed below your own animal will have. Circle your traits below.

Trait	Heads	Tails
1. Coloration	 bright	 dull
2. Size	 large	 small
3. Defenses	 armored spines	 always alone
4. Speed	 fast	 slow
5. Grouping	 always with others	 always alone

Every animal in your population should be a little bit different from the other animals in your group. This is called VARIATION. There is variation in all animals. Just look around!

4. Now draw your animal from step 2 and include the traits flipped for in step 3!



7. The sharks attacked!

To determine if your animal from step 4 survives, score your animal based on its traits listed in step 3. Each player score your own animal below.

Tally points below:

Coloration bright = +0 dull = +1	0
Size large = +0 small = +1	0
Defenses armored spines = +1 no armor = +0	0
Speed fast = +1 slow = +0	0
Grouping always with others = +1 always alone = +0	0
Total Score =	0

8. Compare your score from step 7 to the rest of your group's scores. Did you have the highest score?

Circle: Yes or No No

9. Can an animal's traits affect whether it survives?

Circle: Yes or No Yes

10. Which of the traits listed below can help keep you safe from hungry animals like the sharks. Circle:

a. bright
b. large
c. fast
d. always alone



11. Write the names of the two people with the two highest scoring animals from step 7 below.

• If there is a tie for first place, both win. If there is a tie for 2nd place, both players should roll a die. Write the name of the person who rolls the largest number.

Emily & Cecilia

Congratulations! These two players' animals survived to go onto the next round! The other players' animals did not survive.

or may not be advantageous in the new environment with mate choice. For example, conspicuous traits were harmful in round 1 with predators, but as one student noted, a fancy mating dance in round 2 with mate choice made them "good/they are awesome." In the last scenario, the environment was altered by climate change and human actions. Global warming caused bleaching and a coral death event on the reef. This round was designed to illustrate the key concept that natural selection can be caused by anthropogenic environmental changes. By playing multiple rounds, students recognized that an animal's chance of surviving and reproducing depended on the environment. When the environment changed, traits that were beneficial were either beneficial, neutral, or harmful in the new environment.

FIGURE 3

Map of evolution concepts.

Map of Evolution Concepts

1. Variation

Students flip a coin to determine which traits their animal will have, creating a variable initial population. Each student draws his/her animal.

2. Selection

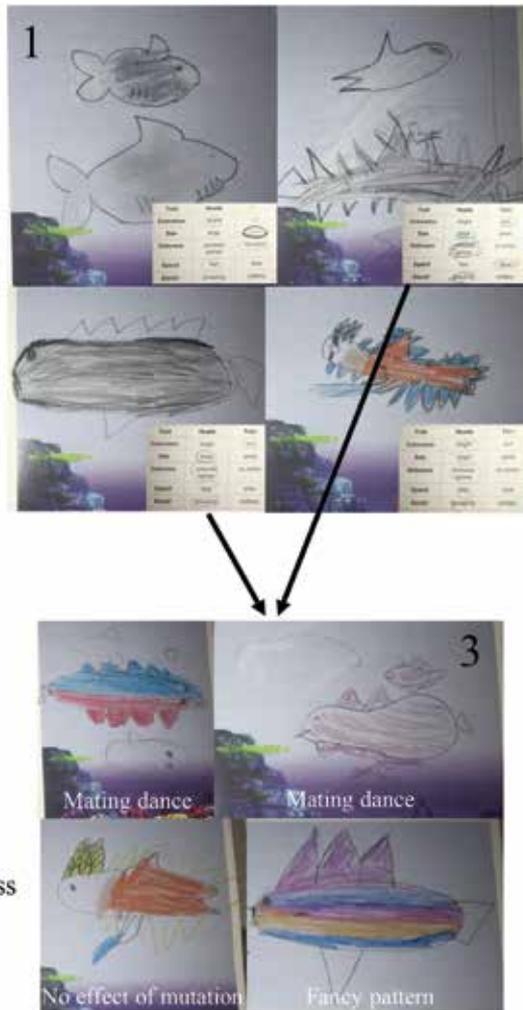
Students score their animals in a given situation (e.g., a shark attack). The two with the lowest scores do not survive.

Trait		Value
Calculation		
Height = +0		
Width = +1		
Size		
Large = +0		
Small = +1		
Defenses		
Antenna = +1		
No armor = +0		
Speed		
Fast = +1		
Slow = +0		
Genes		
Color = +1		
Pattern = +0		
Total Score =		

3. Inheritance

The 2 surviving animals pass on their traits to the next generation. Each individual also receives a random **mutation** (white text).

4. Time Students play 3 rounds so that they can observe change over time, **EVOLUTION!**



bell rang to signal the end of the school day. Students reported that they “love this game.” One student said, “One thing I liked about this game is that I got the most points.” We also received positive feedback from the teacher: “[The game was] highly engaging. It was a little over their heads [referring to vocabulary]... but none of them gave up and they were excited to see what happened.”

There were some challenges that we addressed. Students were at times confused by the vocabulary and sometimes lost their place in the booklet. We revised the booklet, adding page numbers, numbering each step of the game, and referring to the steps throughout the booklet. During the activity, we asked students to raise their hand each time they were confused by a word. We flagged each of those words in the booklet and later replaced them when possible with simpler language. For those challenging words that we included in the booklet, we created a glossary of terms. Because of time constraints and constructive feedback, the biggest change we made was to divide the activity into three separate lessons, dividing the three scenarios in the game. The game can now be played in three days. We suggest spending 45 minutes on the first day and 30 minutes on the two additional days. This provides an opportunity for formative assessment, and instructors can lead short discussion sessions at the end of each lesson to reinforce learning objectives. We created a set of teacher notes (see NSTA Connection) to provide instructors with guidance for classroom management, instructions for how to prepare for this activity, and suggestions for how to tailor this activity to instructor’s specific classrooms to facilitate learning for all types of

students (for example, classrooms with students that have English as a second language or students in individualized education programs).

We measured students’ comprehension of the material presented in the game as well as their ability to apply the learned concepts to novel scenarios by administering a summative assessment (see NSTA Connection). Our students demonstrated a good grasp of the concepts. For example, they recognized that traits that are well-suited to an environment are most likely to be passed on to the next generation because only those animals survive and reproduce; the

Reflection

As students played the game, they were enthusiastic and engaged, and interacted with their own group as well as other groups. For example, students loudly exclaimed when their animals survived a round and were even more vocal when they died. They proudly showed their drawings to their teacher and their peers, running over to other groups to find out which animals survived each round. They also worked together to answer the questions throughout the booklet. Many groups didn’t complete the third round in the 45 minutes and tried to continue playing the game even after the



majority of students correctly identified that a bird's hard beak that allows it to crack open seeds would be likely to be passed on. Students also recognized that an animal's traits were directly related to survival. For example, when faced with a shark predator, one student wrote: "My animal will not survive [sic] because I have no armr [sic]." The results from the assessment suggest that this game is an engaging and effective way to introduce evolution. Now that the game takes place over three days, we encourage teachers to take time in each lesson for formative assessment. We include suggestions for such assessments in the teacher notes. For example, after students experience the first natural selection event, a shark attack, the instructor could ask students to raise their hands if they survived. Next, the instructor could ask students to share any traits their animal had that they think contributed to its survival. If a student said fast speed, for example, the instructor could ask those students that raised their hands before (those that survived) to raise a second hand if their animal was also fast. This could lead to a short discussion about how survival is nonrandom and based on traits (Figure 1, learning objective 1).

Conclusion

The teaching of evolution, while challenging, is critical. Not only are elementary school students capable of understanding key concepts in evolution, teaching of these concepts in elementary school can reduce misconceptions. Major barriers to evolution education are teacher preparedness and lack of resources. Our game is student-led, addresses the learning objectives in the NGSS, and adds to the growing list of evolution-based teaching materials for elementary school classrooms. This generation is moving away from

traditional lecture-style learning to more interactive forms. With minimal and inexpensive materials, our game integrates group-mediated critical thinking, individual creativity, and hands-on learning, making it a powerful tool that can be used widely. ●

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NSTA Connection

Download the activity booklets, teacher notes, and summative assessment at www.nsta.org/SCO120.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard

3-LS4 Biological Evolution: Unity and Diversity

www.nextgenscience.org/dci-arrangement/3-ls4-biological-evolution-unity-and-diversity

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Performance Expectations

3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

3-LS4-3. Construct an argument with evidence that in particular habitats some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

DIMENSIONS

CLASSROOM CONNECTIONS

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Students think about how traits allow animals to survive and reproduce in changing environments.

Engaging in Argument From Evidence

Students use results from each round of the game to understand, define, and discuss key evolutionary concepts: variation, inheritance, mutation, and selection.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Students document survival and reproduction of individuals with different traits using a scoring system when the environment changes over three different scenarios.

LS4.B: Natural Selection

Students observe that differences in traits affect survival, finding mates, and reproduction in each round of the game.

LS4.C: Adaptation

Students observe how individual characteristics determine if an animal survives well, less well, or not at all in each round.

LS4.D: Biodiversity and Humans

Students observe that coral reef bleaching from human impacts acts as a selective force changing the population.

Crosscutting Concept

Cause and Effect

Students identify how variation in traits can explain the differential survival and reproduction of organisms in a population as well as in a particular environment.

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